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**Hung et al.**

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# (54) CHROMELESS PHASE-SHIFTING MASK FOR EQUAL LINE/SPACE DENSE LINE PATTERNS

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This patent is subject to a terminal disclaimer.

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(51) **Int. Cl.**
***G03F 1/00*** (2006.01)

(52) **U.S. Cl.** .......................................................... **430/5**

(58) **Field of Classification Search** ...................... 430/5
See application file for complete search history.

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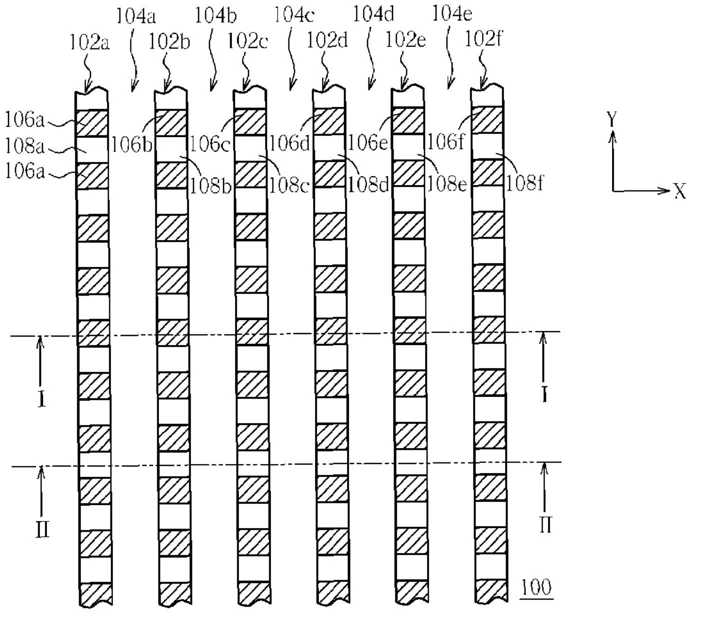
*Assistant Examiner*—Stewart A Fraser
(74) *Attorney, Agent, or Firm*—Winston Hsu

## (57) ABSTRACT

A phase-shifting mask suited for equal line/space, small pitched, dense line pattern is disclosed. The phase-shifting mask includes a transparent substrate, a partially shielded mesa line pattern of first phase formed on the substrate, and a clear recessed line pattern of second phase etched into the substrate and is disposed right next to the partially shielded mesa line pattern. The partially shielded mesa line pattern has a plurality of alternating 5%-10% transmittance light-shielding regions and clear regions of the first phase. The partially shielded mesa line pattern and the clear recessed line pattern have the same line width. The light that passes through the clear regions of the first phase and the light that passes through the clear recessed line pattern of second phase have a phase difference of 180 degree.

**17 Claims, 13 Drawing Sheets**



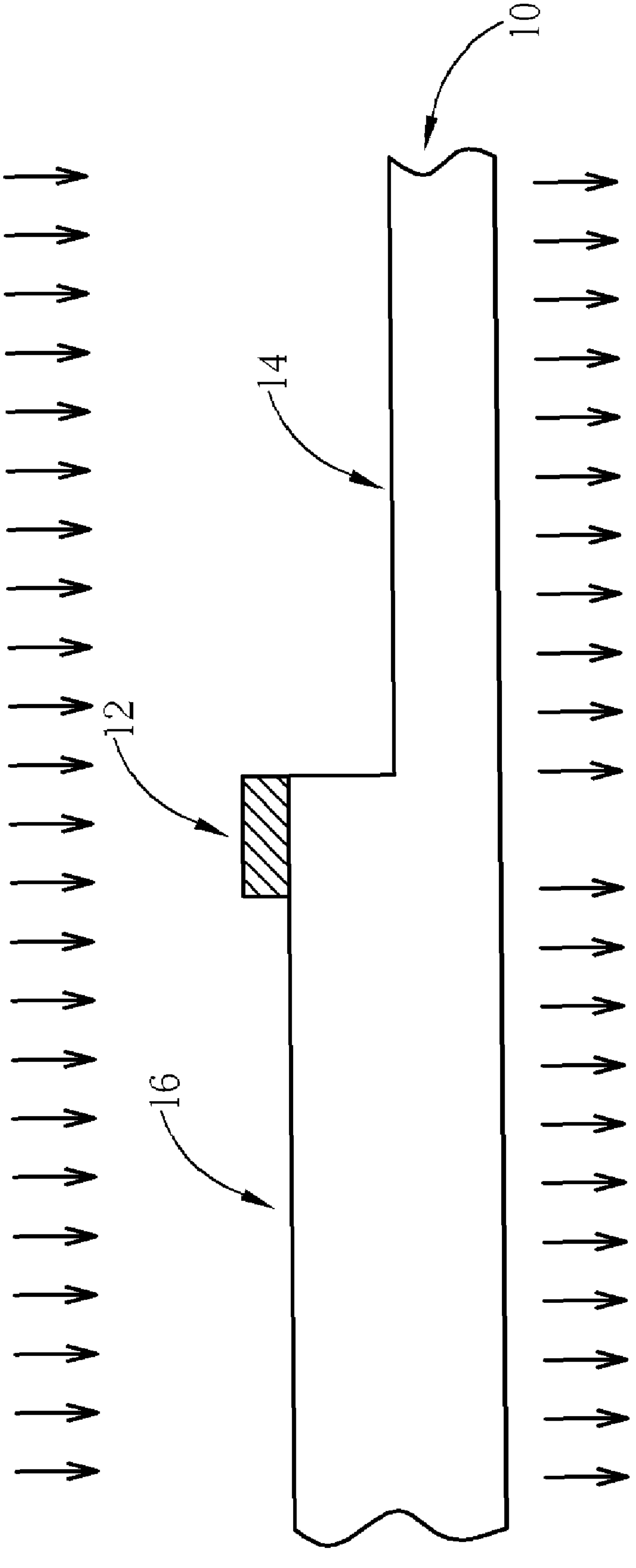


Fig. 1 Prior art

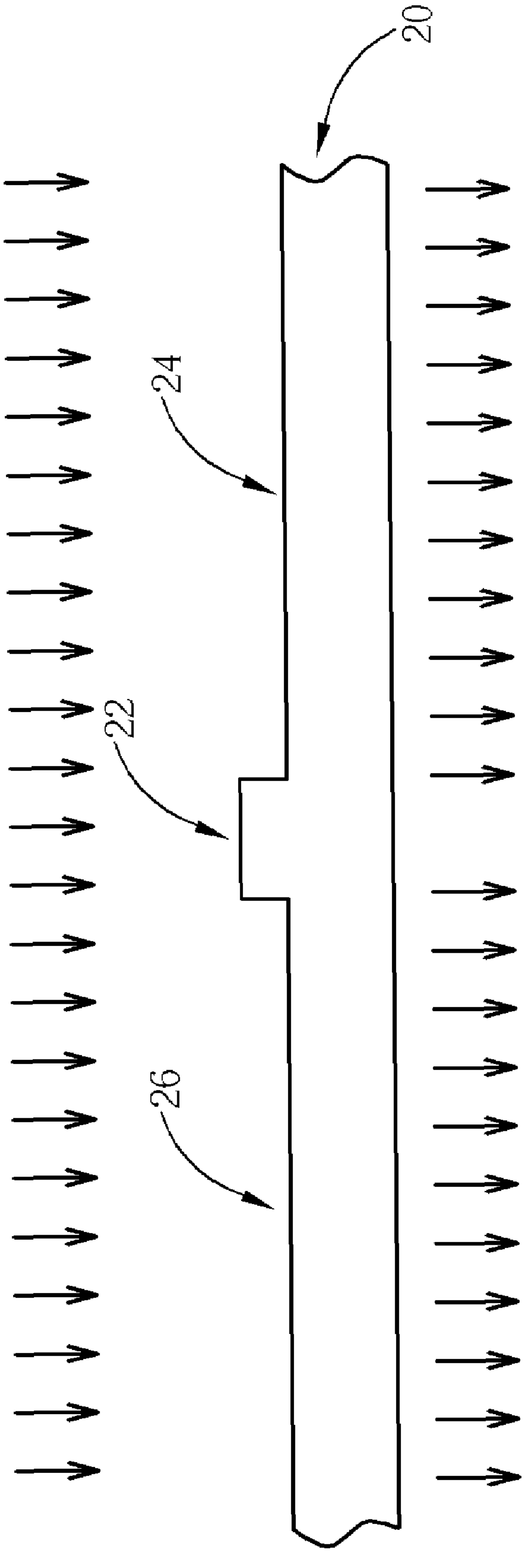


Fig. 2 Prior art

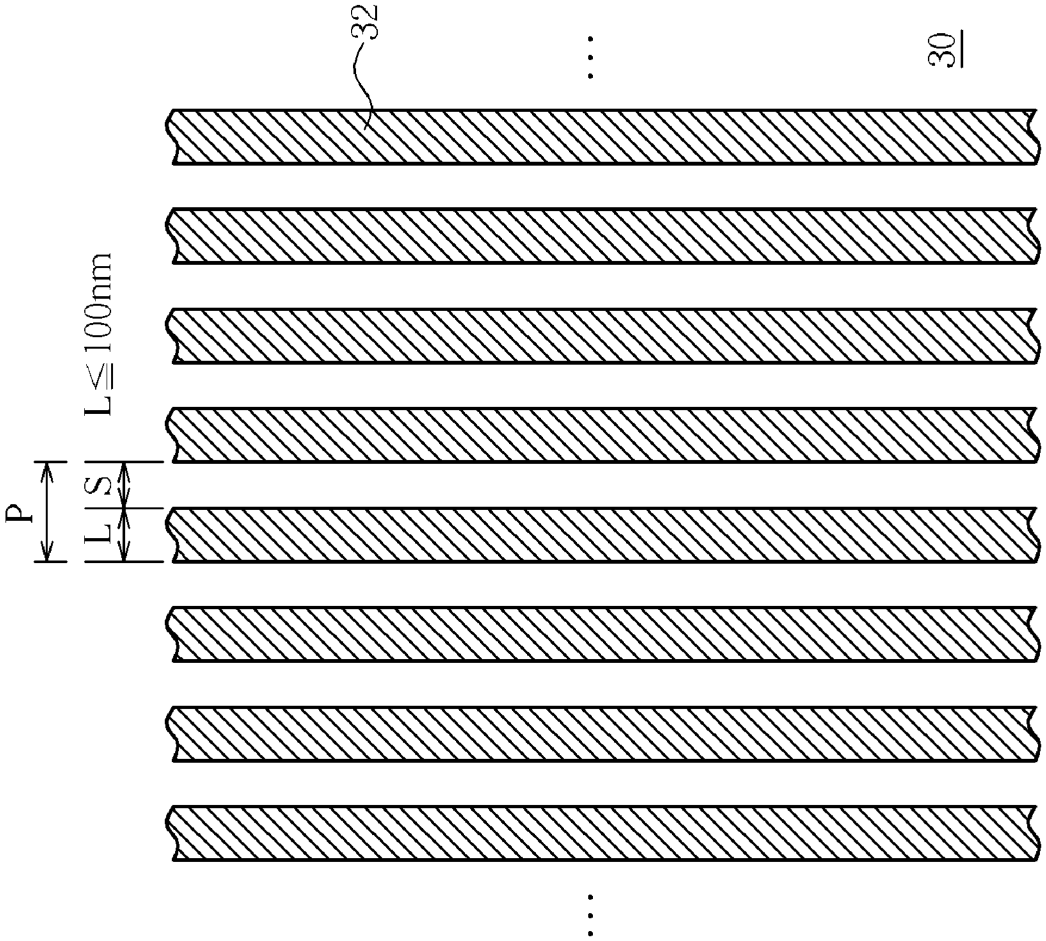
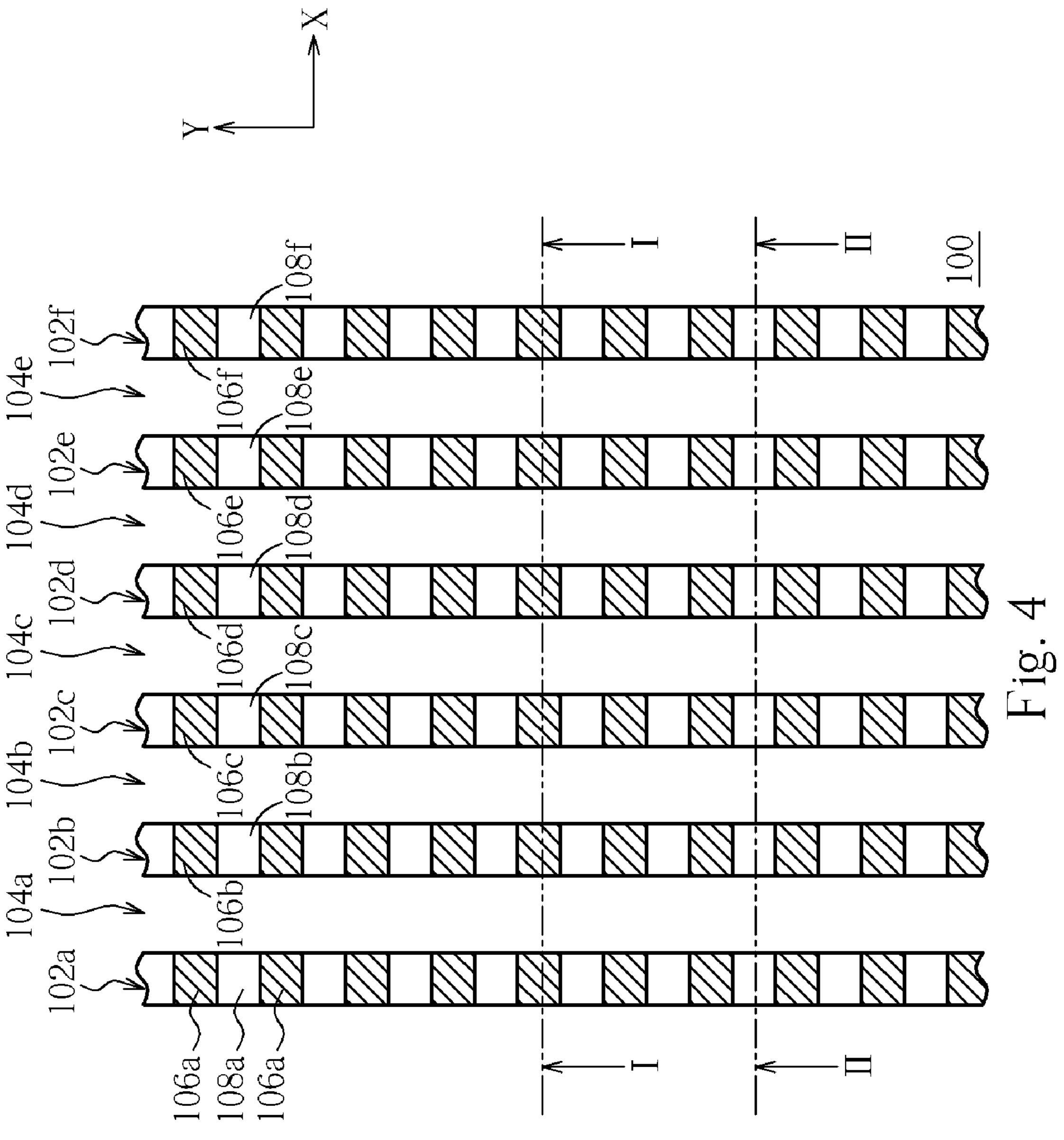


Fig. 3 Prior art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102f
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106a
106b
108b
106c
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106d
108d
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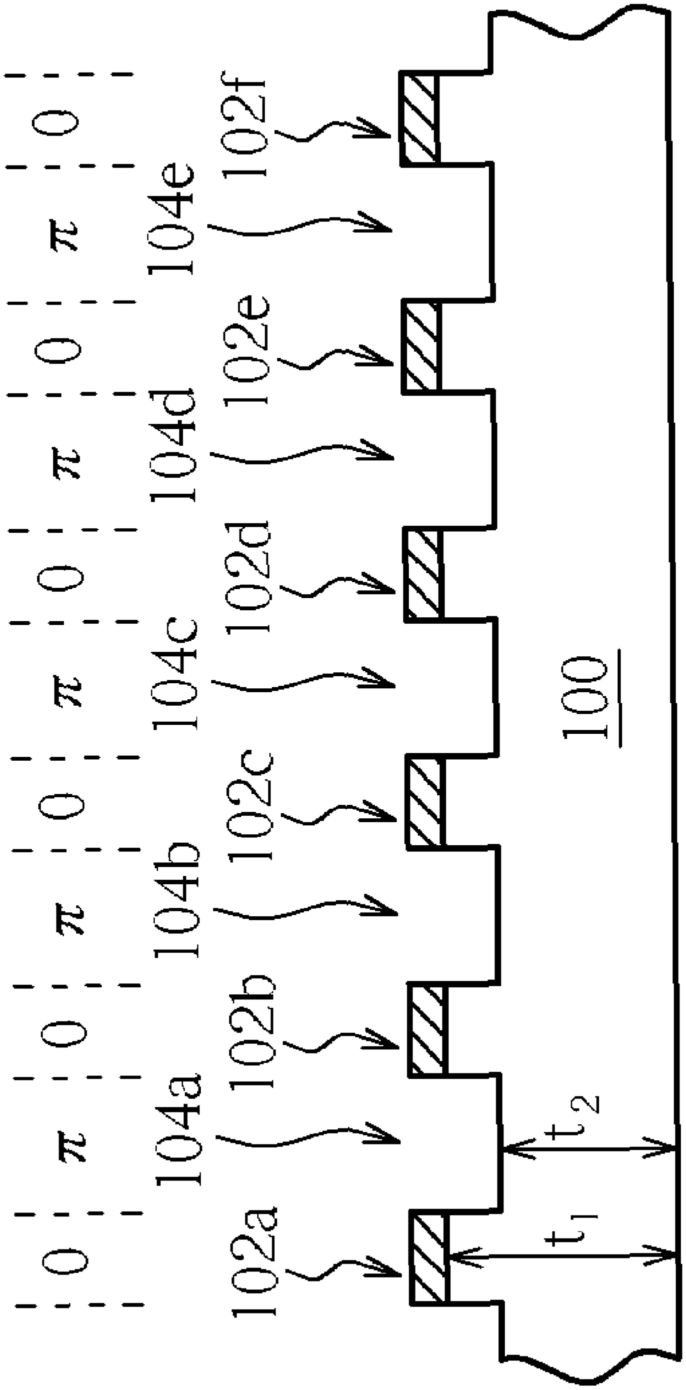
108e
106f
108f
I
I
II
II
100

Fig. 4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104d
102e
104e
102f
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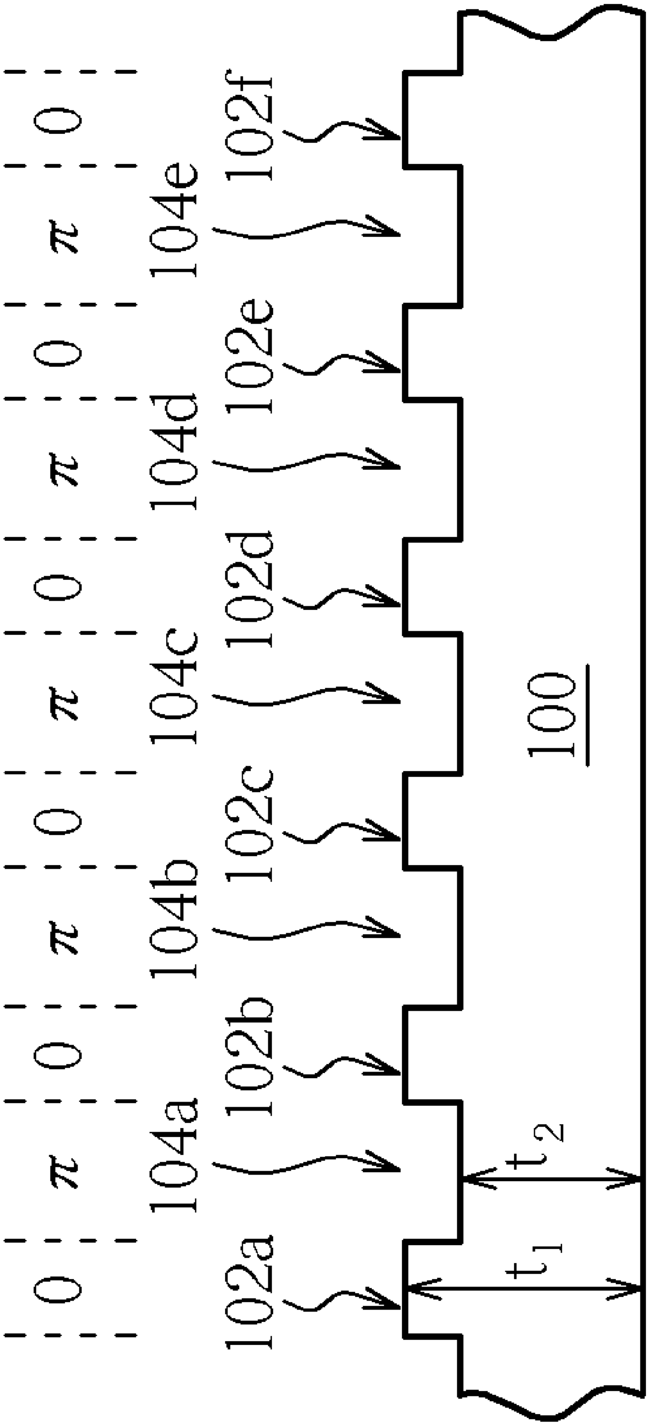
$t_2$
100

Fig. 5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104a
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102e
104e
102f
$t_1$
$t_2$
100

Fig. 6

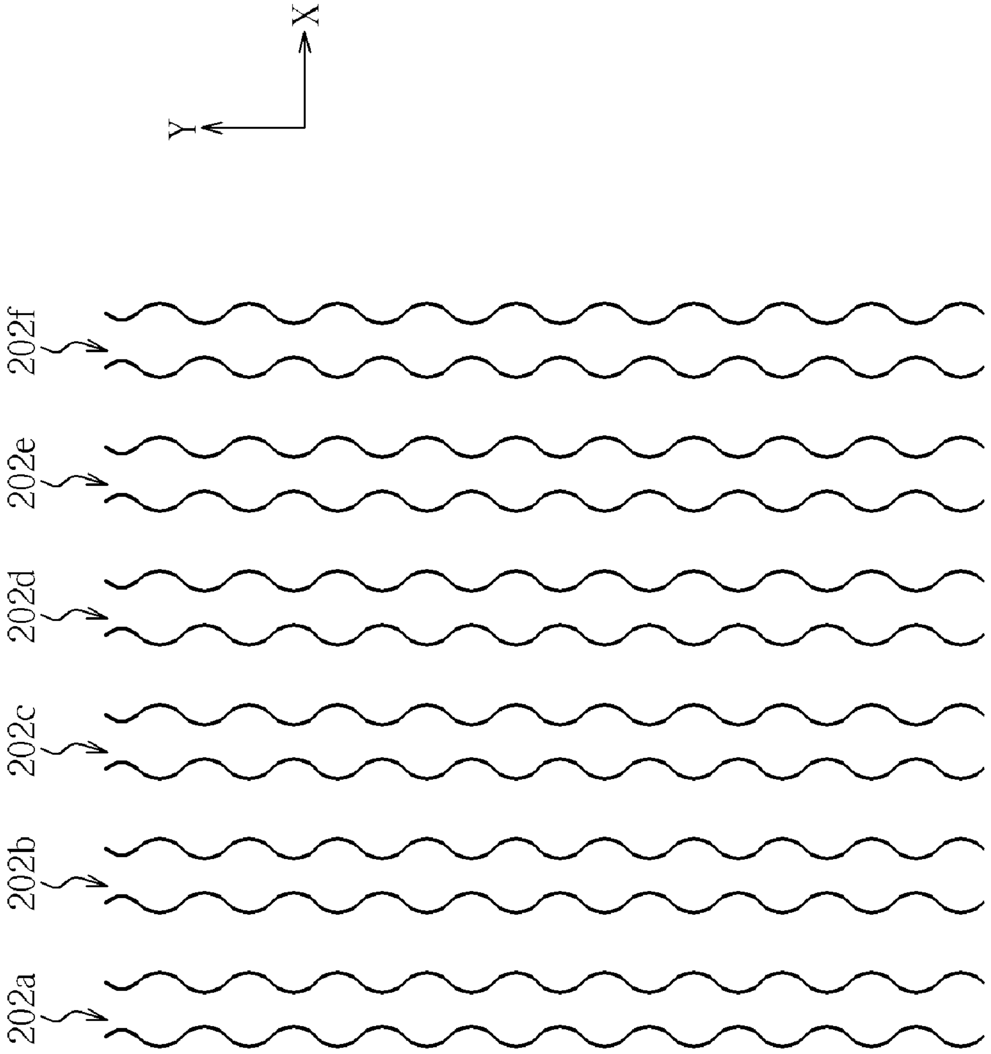
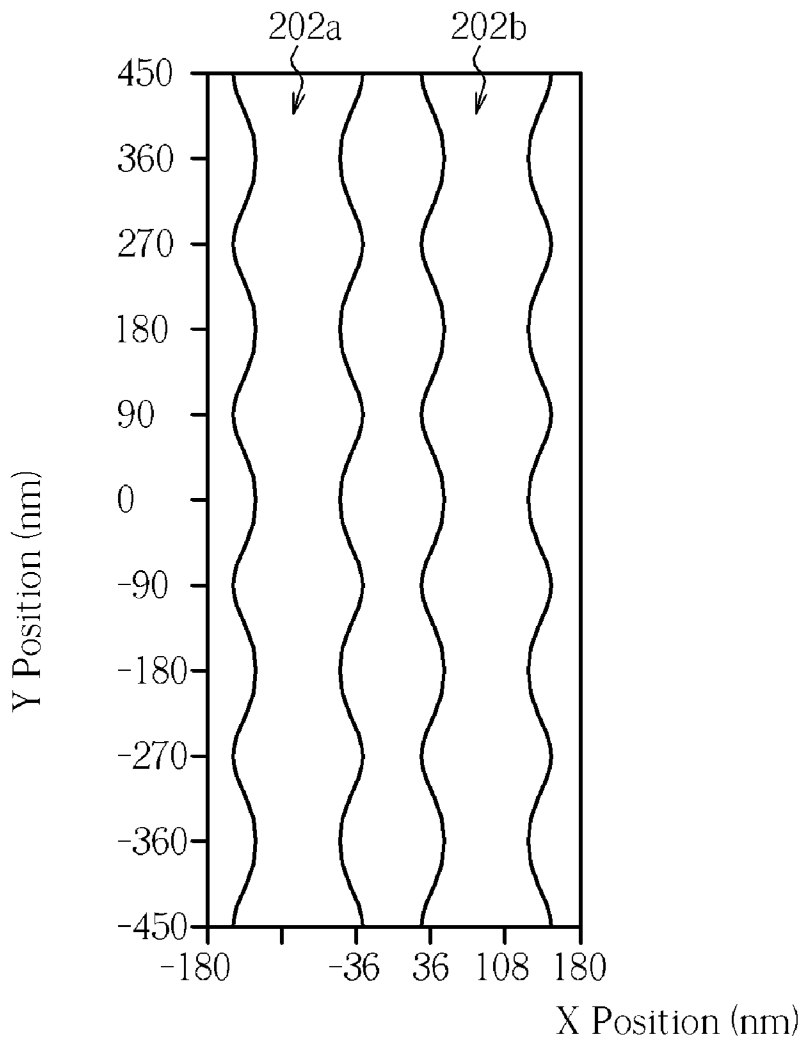


Fig. 7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180
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-36
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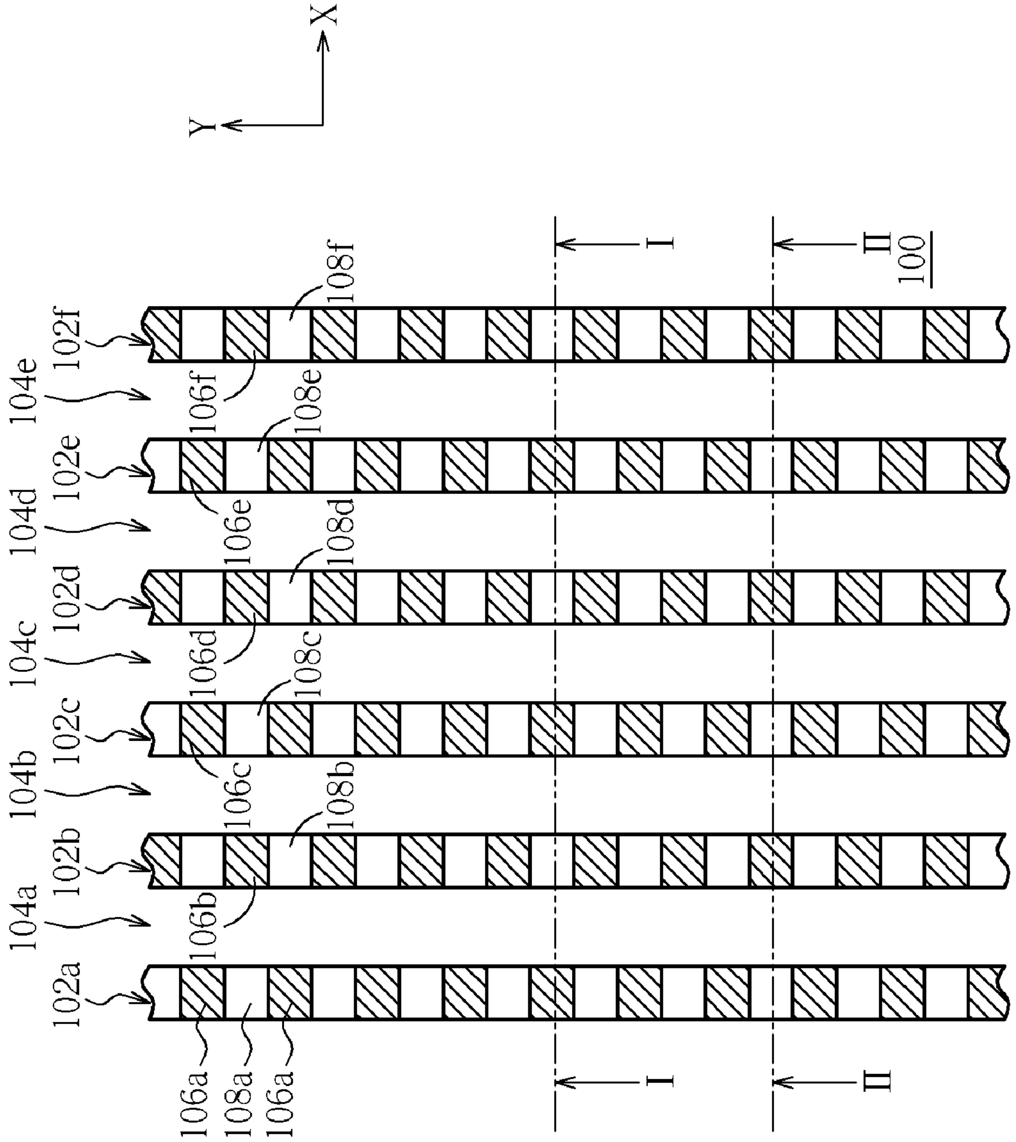
108
180
X Position (nm)

Fig. 8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104d
104e
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108a
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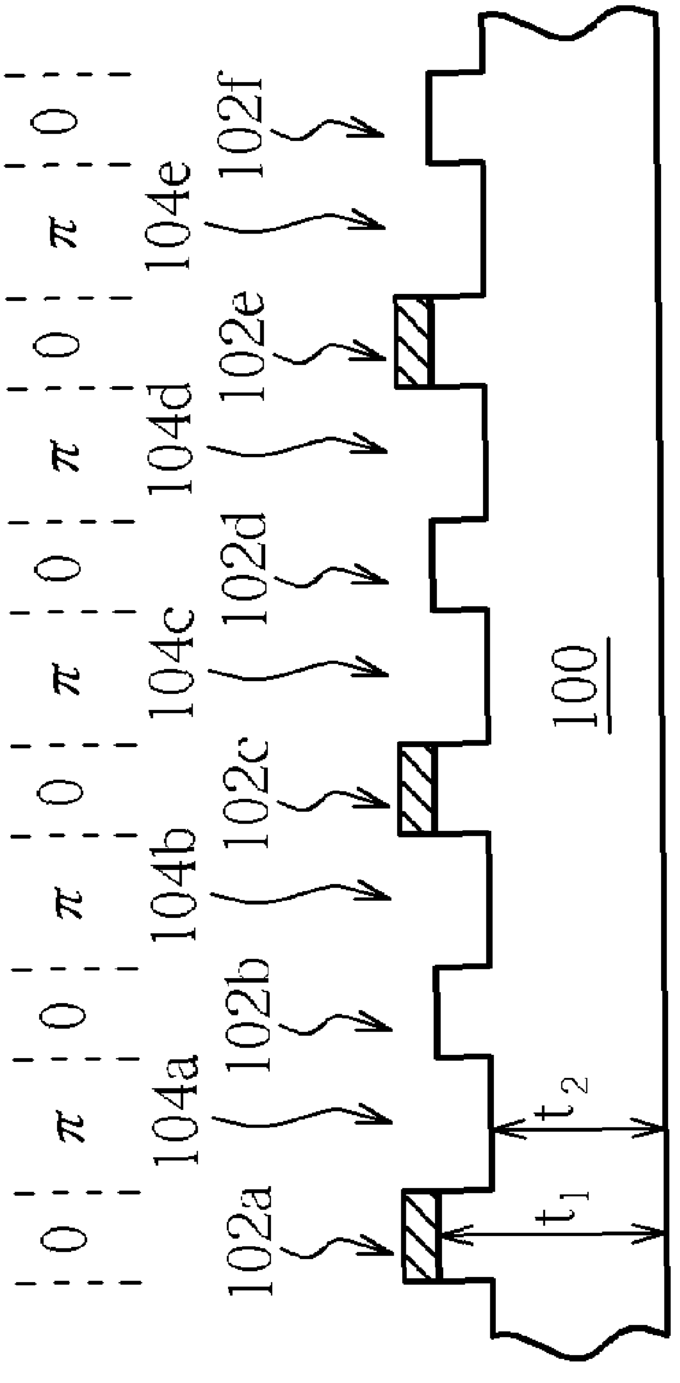
108f
I
I
II
II
100

Fig. 9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π
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π
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π
0
102a
104a
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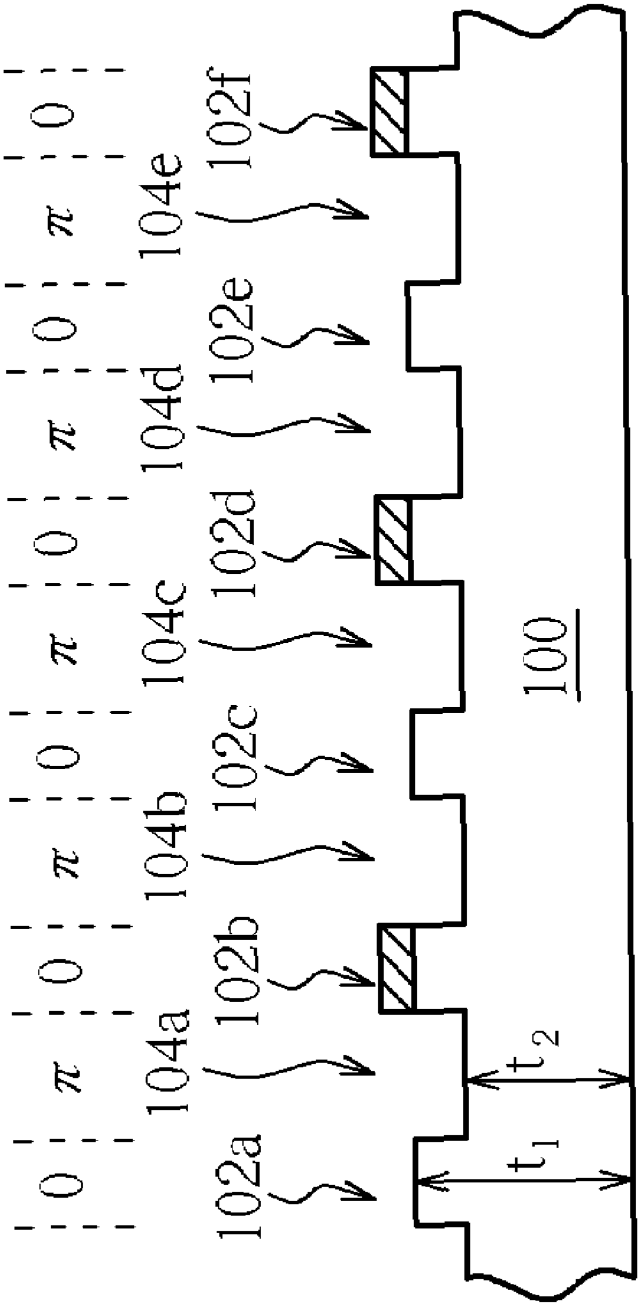
104c
102d
104d
102e
104e
102f
$t_1$
$t_2$
100

Fig. 10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0
π
0
π
0
102a
104a
102b
104b
102c
104c
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104d
102e
104e
102f
$t_1$
$t_2$
100

Fig. 11

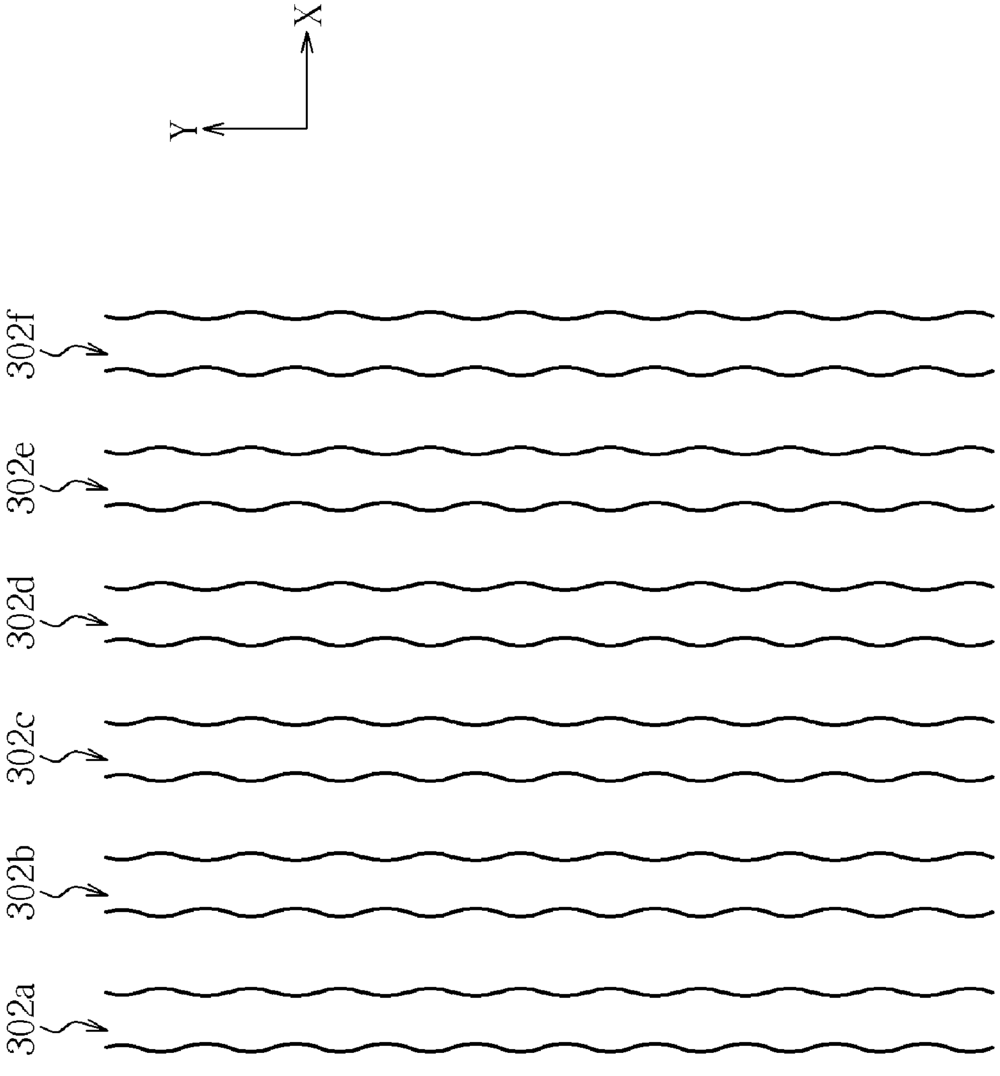

Fig. 12

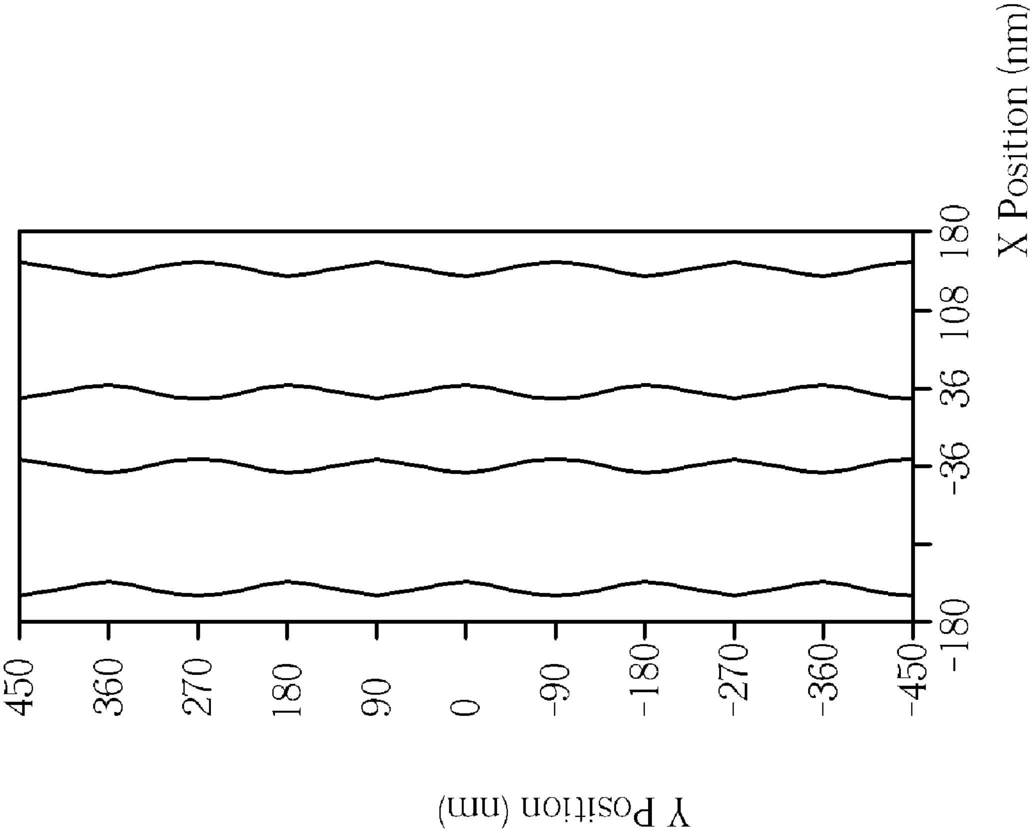
X Position (nm)
180
108
36
-36
-180
Y Position (nm)
450
360
270
180
90
0
-90
-180
-270
-360
-450

Fig. 13

# CHROMELESS PHASE-SHIFTING MASK FOR EQUAL LINE/SPACE DENSE LINE PATTERNS

## BACKGROUND OF INVENTION

1. Field of the Invention

The present invention relates to a phase-shifting mask (PSM), and more particularly, to a chromeless PSM for equal line/space dense line patterns and lithographic method of employing such chromeless PSM.

2. Description of the Prior Art

Lithography processing, which is an essential technology when manufacturing conventional integrated circuits, is used for defining geometries, features, lines, or shapes onto a die or wafer. In the integrated circuit making processes, lithography plays an important role in limiting feature size. By using lithography, a circuit pattern can be precisely transferred onto a die or wafer. Typically, to implement the lithography, a designed pattern such as a circuit layout pattern or an ion doping layout pattern in accordance with a predetermined design rule is created on one or several mask in advance. The pattern on the mask is then transferred by light exposure, with a stepper and scanner, onto the wafer.

It is critical in this field to solve resolution of the lithographic process as the device sizes of the semiconductor industry continue to shrink to the deep sub-micron scale. There are primarily two methods in the prior art for improving resolution. One method involves using short wavelengths of light to expose a photoresist layer on the semiconductor wafer. Short wavelengths of light are desirable as the shorter the wavelength, the higher the possible resolution of the pattern. Another method involves the use of a phase-shifting mask (PSM) to improve the resolution of the pattern transferred to the semiconductor wafer.

Please refer to FIG. **1**, which is a structural diagram of a prior art alternating phase-shifting mask **10**. As shown in FIG. **1**, a fully opaque material such as chrome is used in a non-transparent region **12** of the alternating phase-shifting mask **10**, and the non-transparent region **12** is flanked by transparent regions **14**, **16**. Both of the transparent regions **14**, **16** are made of quartz. The thickness of the transparent region **14** is less than that of the transparent region **16**. Therefore, light that passes through the transparent region **14** has a 180-degree phase shift relative to light that passes through the thicker transparent region **16**, which results in destructive interference and image contrast. Consequently, during the lithographic process, a dark unexposed region falls on an area of a photoresist layer and is located below the non-transparent region **12** of the alternating phase-shifting mask **10**.

However, the alternating phase-shifting mask (alt-PSM) **10** has to perform a double-exposure/two-mask lithography process involving a trim mask to complete pattern transferring. The first mask is a phase-shifting mask and the second mask is a single-phase trim mask. The phase-shifting mask primarily defines regions requiring phase shifting. The single-phase trim mask primarily defines regions not requiring phase shifting. However, this optical proximity correction (OPC) technique suffers from transmission imbalance occurred in phase shifted and non-phase-shifted regions and other flaws caused by alt-PSM.

Therefore, a chromeless phase-shifting mask is developed. Please refer to FIG. **2**, which is a structural diagram of a prior art chromeless phase-shifting mask **20**. As shown in FIG. **2**, the chromeless phase-shifting mask comprises a transparent region **22** made of quartz, and the transparent region **22** is flanked by two transparent regions **24**, **26** also made of quartz. The transparent region **22** is thicker than both the transparent regions **24**, **26**, which causes a 180 degree phase-shifting in light passing through the transparent regions **24**, **26**.

In other words, the transparent regions **24**, **26** are phase-shifting regions, and the transparent region **22** is a non-phase-shifting region. Because of this 180-degree phase difference, there is destructive interference at the phase boundaries of the phase-shifting regions **24**, **26** and the non-phase-shifting region **22**. Consequently, during the lithographic process, a dark unexposed region falls on an area of a photoresist layer and is located below the non-phase-shifting region **22** of the chromeless phase-shifting mask **20**.

However, with the increase of packing density of devices such as dynamic random access memory (DRAM) devices, a pitch between adjacent micro features of the device such as word line pitch shrinks dramatically. Please refer to FIG. **3**. FIG. **3** is a plan view of a portion of word lines **32** overlying a semiconductor wafer **30**. As shown in FIG. **3**, pitch P of the word lines **32** is equal to the combination of line width L and the spacing S between two adjacent word lines **32** (P=L+S). When the line width L is less than or equal to 100 nm, and the pitch P is substantially equal to the twice of the line width L of the device and forms a dense pattern, light of 0 degree phase-shifting and light of 180 degrees phase-shifting cancel out. Therefore, the prior art chromeless phase-shifting mask fails to transfer the dense pattern.

## SUMMARY OF INVENTION

It is therefore an object of the claimed invention to provide a chromeless phase-shifting mask for solving the above-mentioned problems.

According to the claimed invention, a chromeless PSM for forming equal line/space, small pitched, dense line pattern is disclosed. The chromeless PSM includes a transparent substrate, a partially shielded mesa line pattern of first phase formed on the substrate, and a clear recessed line pattern of second phase etched into the substrate and is disposed right next to the partially shielded mesa line pattern. The partially shielded mesa line pattern has a plurality of alternating 5%-10% transmittance light-shielding regions and clear regions of the first phase. The partially shielded mesa line pattern and the clear recessed line pattern have the same line width. The light that passes through the clear regions of the first phase and the light that passes through the clear recessed line pattern of second phase have a phase difference of 180 degree.

From one aspect of this invention, a chromeless PSM comprises a transparent substrate; a plurality of first phase-shifting line patterns having a first substrate thickness of first phase disposed on the transparent substrate along a first direction, wherein each of the first phase-shifting line patterns is disposed thereon clear regions of the first phase and 5%-10% light transmittable block areas. A plurality of 100% light transmittable second phase-shifting line patterns, in parallel with the first phase-shifting line patterns, has a second substrate thickness of second phase. The first phase-shifting line patterns and second phase-shifting line patterns have the same line width and are alternately disposed on the transparent substrate.

These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

## BRIEF DESCRIPTION OF DRAWINGS

The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings:

FIG. **1** is a structural diagram of a prior art alternating phase mask;

FIG. **2** is a structural diagram of a prior art chromeless phase-shifting mask;

FIG. **3** is a plan view of a portion of word lines overlying a semiconductor wafer;

FIG. **4** is a plan view of a portion of the layout of a chromeless PSM in accordance with one preferred embodiment of this invention;

FIG. **5** is a schematic, cross-sectional view of the chromeless PSM taken along line I-I of FIG. **4**;

FIG. **6** is a schematic, cross-sectional view of the chromeless PSM taken along line II-II of FIG. **4**;

FIG. **7** is a plan view of a portion of the resultant equal line/space dense line pattern transferred from the chromeless PSM of this invention to a photoresist film coated on a wafer;

FIG. **8** is a schematic diagram illustrating the CD uniformity of the equal line/space dense line patterns **202***a* and **202***b* of FIG. **7** according to the first preferred embodiment of this invention;

FIG. **9** is a plan view of a portion of the layout of a chromeless PSM in accordance with second preferred embodiment of this invention;

FIG. **10** is a schematic, cross-sectional view of the chromeless PSM taken along line I-I of FIG. **9**;

FIG. **11** is a schematic, cross-sectional view of the chromeless PSM taken along line II-II of FIG. **9**;

FIG. **12** is a plan view of a portion of the resultant equal line/space dense line pattern transferred from the chromeless PSM of FIG. **9** to a photoresist film in accordance with the second embodiment of this invention; and

FIG. **13** is a schematic diagram illustrating the CD uniformity of the equal line/space dense line patterns **202***a* and **202***b* of FIG. **12** according to the second preferred embodiment of this invention.

## DETAILED DESCRIPTION

In describing the preferred embodiment of the present invention, reference will be made herein to FIGS. **4-13** of the drawings, wherein like numerals designate like components, areas or regions. Features of the invention are not drawn to scale in the drawings.

The present invention pertains to an improved chromeless phase-shifting mask (PSM), which is capable of solving equal line/space, small pitched, dense line patterns such as word lines or gate conductors of trench-capacitor dynamic random access memory (DRAM) devices having critical line width that is less than or equal to 100 nanometers. The critical dimension (CD) uniformity of the resultant equal line/space dense line pattern transferred from the chromeless PSM of this invention to a photoresist film coated on a wafer is also enhanced.

Please refer to FIGS. **4-7**, wherein FIG. **4** is a plan view of a portion of the layout of a chromeless PSM in accordance with one preferred embodiment of this invention; FIG. **5** is a schematic, cross-sectional view of the chromeless PSM taken along line I-I of FIG. **4**; FIG. **6** is a schematic, cross-sectional view of the chromeless PSM taken along line II-II of FIG. **4**; FIG. **7** is a plan view of a portion of the resultant equal line/space dense line pattern transferred from the chromeless PSM of this invention to a photoresist film coated on a wafer.

As shown in FIG. **4**, the chromeless PSM in accordance with one preferred embodiment of this invention comprises a transparent quartz substrate **100**, a plurality of first phase-shifting line patterns **102***a*-**102***f* arranged in parallel with each other along the reference Y-axis, and a plurality of second phase-shifting line patterns **104***a*-**104***e* arranged in parallel with each other along the reference Y-axis. According to the preferred embodiment, the line width of each of the first phase-shifting line patterns **102***a*-**102***f* and the line width of each of the second phase-shifting line patterns **104***a*-**104***e* are the same.

The aforesaid first phase-shifting line patterns **102***a*-**102***f* and second phase-shifting line patterns **104***a*-**104***e* are alternately formed on the quartz substrate **100**. By way of example, the second phase-shifting line pattern **104***a* is disposed between the first phase-shifting line pattern **102***a* and the first phase-shifting line pattern **102***b*, the second phase-shifting line pattern **104***b* is disposed between the first phase-shifting line pattern **102***b* and the first phase-shifting line pattern **102***c*, and so forth. Besides, along each of the first phase-shifting line patterns **102***a*-**102***f*, a plurality of block areas **106***a*-**106***f* are provided. The block areas are disposed spaced apart from each other along each of first phase-shifting line patterns **102***a*-**102***f*. As shown in FIG. **4**, for example, a 100%-light transmission first phase-shifting area **108***a* is disposed between two adjacent block areas **106***a* along the first phase-shifting line pattern **102***a*. The block areas are equal in size and have a light transmission rate of about 5%-10%, i.e., merely 5%-10% of the incident light can pass through each of the block areas.

According to the first preferred embodiment, each of the block areas **106***a*-**106***f* is masked by a phase shifter such as MoSi, MoSiO, MoSiON or the like.

Therefore, the second phase-shifting line patterns **104***a*-**104***e* of the chromeless PSM of this invention are 100% light transmittable. Each of the first phase-shifting line patterns **102***a*-**102***f* of the chromeless PSM encompasses alternating 100% light transmittable clear areas and 5%-10% light transmittable block areas. The phase-shifting mask of this invention is partially shielded along the mesa line pattern **102***a*-**102***f* of first phase. According to the first preferred embodiment, the length of one side of each of the rectangular 5%-10% light transmittable block areas **106***a*-**106***f* along the reference Y-axis ranges approximately from $\lambda/4$ to $3\lambda/4$ ($\lambda$: wavelength of the exposure light source of the stepper and scanner, in nanometer). The length of one side of each of the rectangular 100% light transmittable clear areas **108***a*-**108***f* along the reference Y-axis ranges approximately from $\lambda/4$ to $3\lambda/4$.

As shown in FIG. **5** and FIG. **6**, the thickness of the quartz substrate **100** underneath each of the first phase-shifting line patterns **102***a*-**102***f* is denoted as $t_1$, and the thickness of the quartz substrate **100** underneath each of the second phase-shifting line patterns (also referred to as "clear recessed line patterns") **104***a*-**104***e* is denoted as $t_2$, wherein $t_1$ is greater than $t_2 (t_1>t_2)$, such that light passing through the quartz substrate **100** having different thicknesses produces image contrast. The phase difference between the phase of light passed through the first phase-shifting line patterns **102***a*-**102***f* and the phase of light passed through the second phase-shifting line patterns **104**$a$-**104**$e$ is 180 degree. Preferably, the phase of light passed through the first phase-shifting line patterns **102**$a$-**102**$f$ is 0-degree, while the phase of light passed through the second phase-shifting line patterns **104**$a$-**104**$e$ is 180-degree ($\pi$).

According to the first preferred embodiment, the plurality of spaced apart 5%-10% light transmittable block areas **106**$a$-**106**$f$, which are disposed on each of the first phase-shifting line patterns **102**$a$-**102**$f$, are aligned with the reference X-axis. By providing such unique layout of the chromeless PSM, resultant dense line patterns **202**$a$-**202**$f$ transferred from the chromeless PSM of this invention to a photoresist film coated on a wafer is depicted in FIG. **7**. However, the critical dimension (CD) uniformity of the resultant dense line pattern (in equal line/space fashion) is still not satisfactory.

Please refer to FIG. **8**. FIG. **8** is a schematic diagram illustrating the CD uniformity of the equal line/space dense line patterns **202**$a$ and **202**$b$ of FIG. **7** according to the first preferred embodiment of this invention. As can be seen in this figure, the variation of the CD of the line pattern **202**$a$ or **202**$b$ is high, and leads to wavelike line profiles.

Please refer to FIGS. **9-12**, wherein FIG. **9** is a plan view of a portion of the layout of a chromeless PSM in accordance with second preferred embodiment of this invention; FIG. **10** is a schematic, cross-sectional view of the chromeless PSM taken along line I-I of FIG. **9**; FIG. **11** is a schematic, cross-sectional view of the chromeless PSM taken along line II-II of FIG. **9**; FIG. **12** is a plan view of a portion of the resultant equal line/space dense line pattern transferred from the chromeless PSM of FIG. **9** to a photoresist film in accordance with the second embodiment of this invention.

As shown in FIG. **9**, the chromeless PSM in accordance with the second preferred embodiment of this invention comprises a transparent quartz substrate **100**, a plurality of first phase-shifting line patterns **102**$a$-**102**$f$ arranged in parallel with each other along the reference Y-axis, and a plurality of second phase-shifting line patterns **104**$a$-**104**$e$ arranged in parallel with each other along the reference Y-axis. According to the second preferred embodiment, the line width of each of the first phase-shifting line patterns **102**$a$-**102**$f$ and the line width of each of the second phase-shifting line patterns **104**$a$-**104**$e$ are the same.

Likewise, the aforesaid first phase-shifting line patterns **102**$a$-**102**$f$ and second phase-shifting line patterns **104**$a$-**104**$e$ are alternately formed on the quartz substrate **100**. By way of example, the second phase-shifting line pattern **104**$a$ is disposed between the first phase-shifting line pattern **102**$a$ and the first phase-shifting line pattern **102**$b$, the second phase-shifting line pattern **104**$b$ is disposed between the first phase-shifting line pattern **102**$b$ and the first phase-shifting line pattern **102**$c$, and so forth. Besides, along each of the first phase-shifting line patterns **102**$a$-**102**$f$, a plurality of block areas **106**$a$-**106**$f$ are provided. The block areas are disposed equally spaced apart from each other along each of first phase-shifting line patterns **102**$a$-**102**$f$. As shown in FIG. **9**, for example, a 100%-light transmission first phase-shifting area **108**$a$ is disposed between two adjacent block areas **106**$a$ along the first phase-shifting line pattern **102**$a$. These block areas are equal in size and have a light transmission rate of about 5%-10%, i.e., merely 5%-10% of the incident light can pass through each of the block areas.

Therefore, the second phase-shifting line patterns **104**$a$-**104**$e$ of the chromeless PSM of this invention are 100% light transmittable. Each of the first phase-shifting line patterns **102**$a$-**102**$f$ of the chromeless PSM encompasses alternating 100% light transmittable clear areas and 5%-10% light transmittable block areas. According to the second preferred embodiment, the length of one side of each of the rectangular 5%-10% light transmittable block areas **106**$a$-**106**$f$ along the reference Y-axis ranges approximately from $\lambda/4$ to $3\lambda/4$ ($\lambda$: wavelength of the exposure light source of the stepper and scanner in nanometer). The length of one side of each of the rectangular 100% light transmittable clear areas **108**$a$-**108**$f$ along the reference Y-axis ranges approximately from $\lambda/4$ to $3\lambda/4$. Each of the block areas **106**$a$-**106**$f$ may be formed from phase shifter such as MoSi, MoSiO, MoSiON or the like.

As shown in FIG. **10** and FIG. **11**, the thickness of the quartz substrate **100** underneath each of the first phase-shifting line patterns **102**$a$-**102**$f$ is denoted as $t_1$, and the thickness of the quartz substrate **100** underneath each of the second phase-shifting line patterns **104**$a$-**104**$e$ is denoted as $t_2$, wherein $t_1$ is greater than $t_2$ ($t_1>t_2$), such that light passing through the quartz substrate **100** having different thicknesses produces image contrast. The phase difference between the phase of light passed through the first phase-shifting line patterns **102**$a$-**102**$f$ and the phase of light passed through the second phase-shifting line patterns **104**$a$-**104**$e$ is 180 degree. Preferably, the phase of light passed through the first phase-shifting line patterns **102**$a$-**102**$f$ is 0-degree, while the phase of light passed through the second phase-shifting line patterns **104**$a$-**104**$e$ is 180-degree ($\pi$).

According to the second preferred embodiment, the 5%-10% light transmittable block areas on two adjacent first phase-shifting line patterns are not aligned with the reference X-axis. For example, as best seen in FIG. **9**, the spaced apart 5%-10% light transmittable block areas **106**$a$, **106**$c$, and **106**$e$, which are disposed on each of the first phase-shifting line patterns **102**$a$, **102**$c$, and **102**$e$, respectively, are aligned with the reference X-axis, while the spaced apart 5%-10% light transmittable block areas **106**$b$, **106**$d$, and **106**$f$, which are disposed on each of the first phase-shifting line patterns **102**$b$, **102**$d$, and **102**$f$, respectively, are aligned with the reference X-axis. By providing such improved layout of the chromeless PSM, resultant dense line patterns **302**$a$-**302**$f$ transferred from the chromeless PSM of this invention to a photoresist film coated on a wafer is depicted in FIG. **12**. The CD uniformity of the resultant dense line pattern (in equal line/space fashion) is enhanced.

FIG. **13** is a schematic diagram illustrating the CD uniformity of the equal line/space dense line patterns **202**$a$ and **202**$b$ of FIG. **12** according to the second preferred embodiment of this invention. As can be seen in this figure, the variation of the CD of the line pattern **302**$a$ or **302**$b$ is reduced.

Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

**1**. A phase-shifting mask (PSM), comprising:

a transparent substrate;

a first phase-shifting line pattern having multiple first columns, each first column having first transparent regions and first 5%-10% light transmittable block areas intermittently and alternately disposed with respect to the first transparent regions on the transparent substrate along a first direction and multiple second columns respectively having second transparent regions each aligning a corresponding one of the first 5%-10% light transmittable block areas and second 5%-10% light transmittable block areas intermittently and alternately disposed with respect to the second transparent regions on the transparent substrate along the first direction, wherein each second 5%-10% light transmittable block area aligns a corresponding one of the first transparent regions in a second direction; and

a 100% light transmittable second phase-shifting line pattern having multiple columns each sandwiched between two adjacent first column and second column of the first phase-shifting line pattern.

**2**. The PSM of claim **1** wherein the 5%-10% light transmittable block areas are equal in size.

**3**. The PSM of claim **1** wherein the 5%-10% light transmittable block areas are disposed equally spaced apart along each of the first phase-shifting line patterns.

**4**. The PSM of claim **1** wherein the 5%-10% light transmittable block areas on odd columns of the first phase-shifting line patterns are aligned with a second direction normal to the first direction, while the 5%-10% light transmittable block areas on even columns of the first phase-shifting line patterns are aligned with the second direction.

**5**. The PSM of claim **1** wherein each of the 5%-10% light transmittable block areas has a length along the first direction ranging from λ/4 to 3λ/4 (λ: wavelength of exposure light source of a stepper and scanner).

**6**. The PSM of claim **1** wherein each of the first and second transparent regions has a length along the first direction ranging from λ/4 to 3λ/4 (λ: wavelength of exposure light source of a stepper and scanner).

**7**. The PSM of claim **1** wherein the first phase-shifting line pattern has a first substrate thickness and the 100% light transmittable second phase-shifting line pattern has a second substrate thickness, and wherein the first substrate thickness is greater than the second substrate thickness such that light that passes through the first and second transparent regions and light that passes through the 100% light transmittable second phase-shifting line pattern have a phase difference of 180 degree.

**8**. The PSM of claim **1** wherein the transparent substrate is a quartz substrate.

**9**. The PSM of claim **1** wherein the 5%-10% light transmittable block areas comprise phase shifter.

**10**. The PSM of claim **9** wherein the phase shifter comprises MoSi, MoSiO or MoSiON.

**11**. A phase-shifting mask (PSM), comprising:

a transparent substrate;

a first partial light transmittable pattern formed on the transparent substrate;

a second transparent pattern having a height lower than that of the first partial light transmittable pattern formed on the transparent substrate; and

a third transparent pattern having a height lower than that of the second transparent pattern defined between the first partial light transmittable pattern and the second transparent pattern.

**12**. The PSM of claim **11** wherein the first partial light transmittable pattern has a length along a first direction ranging from λ/4 to 3λ/4 (λ: wavelength of exposure light source of a stepper and scanner).

**13**. The PSM of claim **12** wherein the second transparent pattern has a length along the first direction ranging from λ/4 to 3λ/4 (λ: wavelength of exposure light source of a stepper and scanner).

**14**. The PSM of claim **11** wherein the second transparent pattern has a first substrate thickness and the third transparent pattern has a second substrate thickness, and wherein the first substrate thickness is greater than the second substrate thickness such that light that passes through the second transparent pattern and light that passes through the third transparent pattern have a phase difference of 180 degree.

**15**. The PSM of claim **11** wherein the transparent substrate is a quartz substrate.

**16**. The PSM of claim **11** wherein the first partial light transmittable pattern comprises phase shifter.

**17**. The PSM of claim **16** wherein the phase shifter comprises MoSi, MoSiO or MoSiON.

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